

Twist-3 in Proton Nucleon Single Spin Asymmetries

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Abstract

The generation of the single spin asymmetries by the twist 3 effects in QCD is discussed. While the short-distance subprocesses is calculable in the Born approximation, some properties of large distance partonic correlations may be extracted by means of sum rules relating them to the DIS spin structure function g_2 . The simple model for twist 3 part of the latter is proposed. The numerical analysis seems to favor the hypothesis about small value of the gluonic poles contribution to the single asymmetries, while the fermionic poles may lead to the measurable effects.

1 Introduction

The single transverse spin asymmetries are known to be one of the most subtle effects in QCD. They should be proportional to mass scale, and the only scale in "naive" perturbative QCD is that of the current quark mass. The additional suppression [1] comes from the fact, that single asymmetries are related to the antisymmetric part of the density matrix. Due to its hermiticity, the imaginary part of scattering amplitude is relevant. As a result, the spin-dependent contribution to the hard scattering cross section starts at the one-loop level only. More exactly, it is due to the interference of the one-loop spin-flip amplitude and Born non-flip one. At the same time, the Born graphs provide a leading approximation to the spin-averaged cross section and the asymmetry is proportional to α_s .

The more accurate application of perturbative QCD, including twist-3 effects, results in a completely different picture. The twist-3 quark-gluon correlations give rise to the QCD single transverse asymmetries suppressed neither by the quark mass (it is substituted by the hadronic one M) nor by α_s (see e.g. [2, 3] and refs. therein). The collective gluon field of the polarized hadron, in which quark is propagating, provides the latter by the mass of order that of the hadron. This field is also the source of the phase shift and the loop integration in the short-distance subprocess is no more required.

2 QCD Factorization for single asymmetries

This qualitative picture is based [2] on a self-consistent approach to the single asymmetries in twist-3 QCD. As a result, the parton-like expression was obtained. A short-distance part is calculable in perturbative QCD with slightly modified Feynman rules. The imaginary part is produced in the Born approximation due to the extra light-cone integration emerging at the twist-3 level. A long-distance contribution is described by new two-argument parton matrix elements, the so-called quark-gluon correlators (or correlations). The latter should, in principle, be determined experimentally from a "partonometer" process, just like the ordinary parton distributions are determined from the deep inelastic scattering. It is important that a mass parameter implied by the correlators is of order of the polarized hadron mass.

Consider a hard inclusive process with a transverse polarized nucleon.

The term in the cross section proportional to twist-3 correlators can be expressed in the form [2]

$$d\sigma_s = \int dx_1 dx_2 \frac{1}{4} Sp[S_\mu(x_1, x_2)T_\mu(x_1, x_2)], \quad (1)$$

where $S_\mu(x_1, x_2)$ is the coefficient function of parton subprocesses with two quark and one gluon legs; $T_\mu(x_1, x_2)$ depends on parton correlators:

$$T_\mu(x_1, x_2) = \frac{M}{2\pi} (\hat{p}_1 \gamma^5 s_\mu b_A(x_1, x_2) - i\gamma_\rho \epsilon^{\rho\mu sp_1} b_V(x_1, x_2)), \quad (2)$$

where $\epsilon^{\rho\mu sp_1} = \epsilon^{\rho\mu\alpha\beta} s_\alpha p_{1\beta}$, s_μ is the covariant hadron polarization vector and M is the hadron mass. Two-argument distributions (correlators)

$$b_A(x_1, x_2) = \frac{1}{M} \int \frac{d\lambda_1 d\lambda_2}{2\pi} e^{i\lambda_1(x_1-x_2)+i\lambda_2 x_2} \langle p_1, s | \bar{\psi}(0) \hat{n} \gamma^5 (D(\lambda_1) s) \psi(\lambda_2) | p_1, s \rangle, \quad (3)$$

$$b_V(x_1, x_2) = \frac{i}{M} \int \frac{d\lambda_1 d\lambda_2}{2\pi} e^{i\lambda_1(x_1-x_2)+i\lambda_2 x_2} \epsilon^{\mu sp_1 n} \langle p_1, s | \bar{\psi}(0) \hat{n} D_\mu(\lambda_1) \psi(\lambda_2) | p_1, s \rangle \quad (4)$$

are real and dimensionless. They possess symmetry properties which follow from T-invariance

$$b_A(x_1, x_2) = b_A(x_2, x_1), \quad b_V(x_1, x_2) = -b_V(x_2, x_1). \quad (5)$$

It is convenient to decompose these functions to the singular and regular pieces:

$$\begin{aligned} b_A(x_1, x_2) &= \varphi_A(x_1) \delta(x_1 - x_2) + b_A^r(x_2, x_1), \\ b_V(x_1, x_2) &= \frac{\varphi_V(x_1)}{x_1 - x_2} + b_V^r(x_1, x_2). \end{aligned} \quad (6)$$

The different form of the singular pieces is dictated by different symmetry properties and is of different physical origin. The "short-range" δ -correlation in b_A is due to the ordinary derivative coming from the transverse momentum.

At the same time, the pole residue in b_V

$$\varphi_V(x_1) = (x_1 - x_2) b_V(x_1, x_2) |_{x_1=x_2} \quad (7)$$

by use of the equation of motion is just the matrix element appearing in the "gluonic pole" contribution of J. Qiu and G. Sterman [3]. These authors suggested such a term because of the pole of the gluonic propagator in the partonic subprocess, producing the imaginary phase which is necessary to have the single asymmetry. However, it is natural to use this term for the pole of the correlation as well.

3 Sum rules for partonic correlations

The quark equation of motion for each flavour allows to relate them to the "transverse" spin-dependent quark distribution

$$\frac{1}{2\pi} \int dx dy (b_A(y, x) [\sigma(x) + \sigma(y)] - [\sigma(x) - \sigma(y)] b_V(y, x)) = \quad (8)$$

$$2 \int dx \sigma(x) x c_T^A(x).$$

Here $\sigma(x)$ is an arbitrary test function. The independence on the choice of the vector n , fixing gauge and transverse direction results in the relation:

$$\frac{1}{2\pi} \int dx dy (b_A(y, x) \frac{\sigma(x) - \sigma(y)}{x - y}) = \int dx \sigma(x) (c_L^A(x) - c_T^A(x)), \quad (9)$$

where $c_L^A(x)$ is the most familiar distribution of the longitudinally polarized quarks. All the integrals in (8,9) are performed in the regions $|x, y, x - y| \leq 1$. For ordinary parton distributions positive arguments correspond to the quarks and the negative ones – to the antiquarks. In the Born approximation the structure functions g_1 and g_2 are:

$$g_1(x) + g_2(x) = \frac{1}{2} \sum_f e^2 (c_T(x) + c_T(-x)) \quad (10)$$

$$g_1(x) = \frac{1}{2} \sum_f e^2 (c_L(x) + c_L(-x))$$

The quark-gluon correlations in our approach combine the contributions, related to the terms of twist 2 and 3 in the operator product expansion. However, it appears possible to separate them just from the physical reasons.

Note that matrix elements, containing the covariant derivative, are actually *not* gauge invariant. This is because the derivative and the quark field it is acting on are taken in the different points at the light cone. One can easily pass to the gauge-invariant form by shifting gluon field to the point of quark field and expressing the compensating term $A^\mu(\lambda_1) - A^\mu(\lambda_2)$ in terms of the gluon strength (the latter is possible because the axial gauge is used). This contradicts the earlier statements [5] that transverse momentum and gluon field are combined together in a gauge-invariant way. One may *separate* these contributions, extracting the short-distance part of the correlation (7), coming from the transverse momentum and the part of gluon field composing the covariant derivative. In this approximation

$$b_A(x_1, x_2) = \varphi_A(x_1)\delta(x_1 - x_2), \quad b_V(x_1, x_2) = 0. \quad (11)$$

The spin structure functions are then completely determined by the transverse momentum distribution

$$\begin{aligned} g_1(x) + g_2(x) &= \frac{1}{2} \sum_f e^2 \frac{\varphi_A(x) - \varphi_A(-x)}{x} \\ g_2(x) &= \frac{1}{2} \sum_f e^2 \frac{d}{dx} (\varphi_A(x) - \varphi_A(-x)), \end{aligned} \quad (12)$$

which may be excluded from these equations. As a result, one gets the simple differential equation, whose obvious solution

$$g_1(x) + g_2(x) = \int_x^1 dx \frac{g_1(x)}{x} \quad (13)$$

after calculation of the moments

$$\int_0^1 x^n \left(\frac{n}{n+1} g_1(x) + g_2(x) \right) dx = 0; \quad (14)$$

is nothing else than Wandzura-Wilczek (WW)[6] sum rules. Originally they were derived in the framework of the operator product expansion for the "twist-2" part of g_2 related to the totally symmetric operators. Therefore,

the twist-2 approximation corresponds to the taking into account the transverse degrees of freedom of polarized quark [7] (the same result was obtained recently by P. Mulders and R. Tangerman using the different approach [8]).

One may easily calculate the gluonic corrections to these sum rule [4], defining the twist-3 part \bar{g}_2 , combining (8), (9), (10 and (7) and taking into account, that only regular piece of b_A contributes:

$$\begin{aligned} \int_0^1 x^n \bar{g}_2(x) dx &= \int_0^1 x^n \left(\frac{n}{n+1} g_1(x) + g_2(x) \right) dx = \\ &= -\frac{1}{\pi(n+1)} \int_{|x_1, x_2, x_1-x_2| \leq 1} dx_1 dx_2 \sum_f e_f^2 \left[\frac{n}{2} b_V(x_1, x_2) (x_1^{n-1} - x_2^{n-1}) + \right. \\ &\quad \left. b_A^r(x_1, x_2) \phi_n(x_1, x_2) \right], \quad \phi_n(x, y) = \frac{x^n - y^n}{x - y} - \frac{n}{2} (x^{n-1} - y^{n-1}), \quad n = 0, 2, \dots \end{aligned} \quad (15)$$

Let us consider the important particular cases. For the analysis of the famous Burkhardt-Cottingham [11] sum rule ($n = 0$) one may use the expression for g_2 , generated by the (regularized) δ -function as a test function in (9)

$$g_2(x) = \frac{1}{2\pi} \int_{|x, y, x-y| \leq 1} dx dy \frac{b^A(x, y) + b^A(y, x)}{x - y}. \quad (16)$$

One of the possibilities for BC sum rule violation is the *long-range* singularity $\delta(x)$ [9]. If g_2 contains such a term proportional to $\delta(x)$, which can never be observed experimentally, it will give a non-zero contribution to the integral and therefore will violate the BC sum rule. Note that such a situation was first noticed by Ahmed and Ross in their pioneer paper on spin effects in QCD [10], where they also mentioned a similarity with the Schwinger term sum rule for the longitudinal structure function. However, to obtain such a behavior, one also needs to have a singularity in b^A e.g.

$$b^A(x, y) = \delta(x) \phi(x, y) + \delta(y) \phi(y, x), \quad (17)$$

where ϕ is regular function. Such a singularity should result in meaningless infinite fermionic poles (when $x = 0$) contribution to single asymmetries.

While these arguments allow one to impose some restrictions for g_2 starting from single asymmetries, the most interesting for our purposes is the 'opposite' problem: what can we learn about twist 3 single asymmetries having some information about twist 3 contribution to g_2 .

4 Quantitative estimates of single asymmetries and model for twist-3 part of g_2

The first numerical estimate was performed a couple of years ago [12]. The starting point was the value of $\int_0^1 dx x^2 g_2(x)$, calculated in the framework of QCD sum rule method [13]. Using the model assumptions about the constance of chromomagnetic field inside the nucleon, the authors estimated quantitatively the gluonic poles contribution to the single asymmetry of direct photon production.

To understand this problem better it instructive to consider (15) for $n=2$ [4].

$$\begin{aligned} \int_0^1 x^2 \hat{g}_2(x) dx = \\ -\frac{1}{3\pi} \int_{|x_1, x_2, x_1-x_2| \leq 1} dx_1 dx_2 \sum_f e_f^2 b_V(x_1, x_2) (x_1 - x_2). \end{aligned} \quad (18)$$

Note that only *vector* correlation contribute to this first nonzero moment. This fact, known for many years, is especially clear from the non-local OPE [14] in the co-ordinate space:

$$\begin{aligned} \{T \bar{\psi} \gamma^\mu \psi(x) \bar{\psi} \gamma^\nu \psi(y)\}_{[\mu\nu]} &= \epsilon^{\mu\nu\rho\sigma} \{i \partial_\rho^x D^c(x, y) \bar{\psi}(x) \gamma_\sigma \gamma_5 U(x, y) \psi(y) \\ &- g D^c(x, y) \bar{\psi}(x) \gamma_\sigma \gamma_5 \int_0^1 dt (t - \frac{1}{2}) (x - y)^\lambda U(x, z) F_{\rho\lambda}(z) U(z, y) \psi(y) \\ &- i g D^c(x, y) \bar{\psi}(x) \gamma_\sigma \int_0^1 dt \frac{1}{2} U(x, z) \tilde{F}_{\rho\lambda}(z(t)) (x - y)^\lambda U(z, y) \psi(y)\}. \end{aligned} \quad (19)$$

The term $\bar{\psi}(0) \gamma_\sigma \gamma_5 F_{\rho\lambda}(0) \psi(0)$ contributing to the second moment of g_2 contains the factor $\int_0^1 dt (t - \frac{1}{2}) = 0$

The sum rule (18) is especially simple when one neglect the regular piece of b_V :

$$\int_0^1 x^2 \bar{g}_2(x) dx = -\frac{1}{3\pi} \int_{|x_1, x_2, x_1-x_2| \leq 1} dx_1 dx_2 \sum_f e_f^2 \varphi_V(x_1). \quad (20)$$

Performing the integration over x_2 one get:

$$\int_0^1 x^2 \bar{g}_2(x) dx = -\frac{1}{3\pi} \int_{-1}^1 dx_1 \sum_f e_f^2 \varphi_V(x_1) (2 - |x_1|). \quad (21)$$

The contribution of the first term in the bracket coincides, up to a constant of order 1, with the sum rule derived [12] by use of the model assumption about the constant collective gluon field. This is quite natural, because the gluonic pole in the correlation is produced by the integration over large distances at the light cone, corresponding to the quasiclassical collective fields. The second term, effectively increasing the correlation for given value of \bar{g}_2 , is produced by the shape of integration region. The latter is related to the analytical properties of the correlations and is therefore a pure quantum effect.

The second moment of \bar{g}_2 was calculated, as it was mentioned above, in the framework of QCD sum rules[13]. These calculation was checked recently [15] by use of the another interpolating nucleon currents, explicitly accounting for the gluonic degrees of freedom. The results are compatible: this moment is small (about 10^{-2}) and negative for the proton case, while for the neutron it is about of order of magnitude larger. Consequently, the single asymmetry of direct photon production is claimed to be small and strongly flavour-dependent.

One should note, however, that only gluonic poles contribution calculated by J. Qiu and G. Sterman was taken into account. At the same time, the contribution of fermionic poles (when imaginary part is produced by the pole of quark propagator) is related to the correlation b_A , which is not manifested at all for the second moment of g_2 .

While the fermionic poles were suggested originally as a source of single asymmetries [2], the gluonic poles were discovered later [3] and claimed the dominant contribution (because it is more easy to emit the zero-momentum gluon than zero momentum quark; note, however, that such emission is known to produce the IR divergencies and may therefore cancel somehow).

Now, when QCD sum rules tell us that gluonic poles are, contrary to these expectations, small, there are two opportunities. First (seems to be now silently accepted) is to believe that the contributions of fermionic poles are even smaller. Second, which we study here, is to come back to fermionic poles and investigate them more seriously.

To do this one may, say, repeat the QCD SR calculation substituting $\tilde{F} \rightarrow F, \gamma_\sigma \rightarrow \gamma_\sigma \gamma_5$. This operator, as it was already explained, does not contribute to g_2 . However, its non-local generalization is directly related to b_A . If one observe its magnitude larger enough than that of vector operator, this would be the strong support that only the gluonic poles are small. The same may be probably performed by modifying the existing lattice [16] calculation of the second moment of \bar{g}_2 .

As we do not know the value of this matrix element at the moment, let us try to perform at least the model estimates. To do this, another sum rule, relating the *first* moments of g_1 and g_2 , is extremely useful. It is known for several years [4], although the role of valence quarks was emphasized only recently [17].

The applicability of the correlations to the single asymmetries is possible because they are the (generalized) distribution functions on the light cone, accumulating the large-distance dynamics. This allows one to apply (8,9) with the *odd* test function and produce sum rules, which can never appear in the framework of the operator product expansion, because they corresponds to the "wrong" moments (the positive parity of two photons pick up the even combinations only). In these cases the combinations $c_{L,T}(x) - c_{L,T}(-x)$ appear. They are just the *valence* quark contributions. As a result, the sum rules (15) are valid for $n = 1, 3, \dots$ with the g_1, g_2 in the l.h.s. being replaced by their valence parts. The case of $n = 1$ is especially interesting, because the contribution of the correlations in the r.h.s. appears to be equal to zero.

$$\int_0^1 dx x (g_1^{val}(x) + 2g_2^{val}(x)) = 0 \quad (22)$$

This sum rule allows one to relate such a "model" entities as valence quark starting from the QCD correlations. The situation here is in some sense opposite to, say, Gottfried sum rule. Instead of "model" derivation for measurable functions, we have (more or less) rigorous QCD derivation for "model" functions. Note that this sum rule is not affected by the possible $1/x^2$ singularity, spoiling the validity of BC sum rule [18].

The valence contribution to g_2 may be measured, in principle, by considering the semi-inclusive asymmetries in DIS on transversely polarized target, in complete analogy with the studies of longitudinal valence distributions at CERN [19]. Although the transverse polarization is, generally speaking, the non-probabilistic twist 3 effect, the parton-like formula (10) for DIS allows

one to extract the valence parts of c_T (and, by use of (8), of the correlations), applying the same formulas as for the longitudinal polarization. One should just change the longitudinal semi-inclusive asymmetries for the transverse ones, and c_L to c_T .

The alternative derivation of this sum rule [18] leads to its validity for *total* structure functions. One may guess that it is valid for quark and antiquarks separately. The other opportunity is [20] that the quark-gluon correlations are negligible, if the signs of x_1 and x_2 are opposite (i.e., the correlation of gluon and quark-antiquark pair is considered). It is interesting, that in this case one should change $2 - |x_1| \rightarrow 1$ in the sum rule for the second moment (20) and get the expression completely analogous to its model derivation [12]. Anyway, let us neglect in the following the difference between valence and total contribution to g_2 .

As a result, the WW sum rules appear to be exact (in the leading twist 3 approximation) for the *two* moments. Consequently, the deviation of g_2 from its WW value (twist 3 piece) has these moments equal to zero. This function should change sign at least two times inside the region $(0,1)$. The similar behavior was predicted for the singlet piece of the tensor spin structure function[21].

Let us incorporate this property to the following parametrization of the twist 3 contribution, where, as usual, the Regge behavior for small x and the phase space for $x \sim 1$ are manifested:

$$\bar{g}_2(x) = Cx^{-\alpha}(x - a_1)(x - a_2)(1 - x)^\beta \quad (23)$$

Imposing the conditions

$$\int_0^1 dx \bar{g}_2(x) = \int_0^1 dx x \bar{g}_2(x) = 0 \quad (24)$$

allows us to find the crossing points a_1 and a_2 in terms of α and β . At the final stage, we shall calculate the second moment of g_2 .

We performed these calculation for $\beta = 4$ and α changing in the interval $[0,1)$. As one should not take this parametrization too seriously, the general features, not very sensitive to the actual values of parameters, are most important:

i) The function has the negative minimum at $x \sim 0.12 \pm 0.05$ and the positive maximum at $x \sim 0.6 \pm 0.05$.

- ii) The second moment is rather small and negative – about $-10^{-3}C$.
- iii) The ratio of the value of function in the minimum to the value of the second moment is changing in the interval $-(70 - 130)$, while for the maximum it is $+(10 - 20)$.

One may expect, that the small value of the second moment, predicted by QCD sum rules, is reflecting the strong oscillations rather than small normalization. This is also compatible with the dominance of axial correlation, absent for the second moment but manifested in another moments and in the fermionic poles contributions to single asymmetries.

Taking into account the negative QCD SR value, one should expect the maximal value of \bar{g}_2 at $x \sim 0.1$ to be *positive*.

$$\begin{aligned}\bar{g}_2^p(x = 0.12 \pm 0.05) &= 0.16 \pm 0.10; \\ \bar{g}_2^n(x = 0.12 \pm 0.05) &= 0.8 \pm 0.4;\end{aligned}\tag{25}$$

While the preliminary data of E143 experiment reported in Morionde were negative in this region (supporting the positive value of the second moment), the more recent data [22] are indicating (for one of two spectrometers) the positive values compatible with (25). However, they are still compatible with zero as well, and the more precise HERMES data are most welcomed.

5 Short-distance subprocesses

Let us discuss briefly the calculation of the short-distance QCD subprocess. It is determined by Born graph (the imaginary part is produced by the pole of the propagator while the integration over light-cone variable is performed) and the computation is straightforward. Note that a number of fermionic poles contributions to quark-gluon subprocesses is already calculated [23]. This offer a possibility not to limit the future experimental studies by the asymmetries of the direct photon production.

I would like to stress the special role of the single asymmetries of jet production. This asymmetry is just

$$A = \frac{\sigma_L - \sigma_R}{\sigma_L + \sigma_R},\tag{26}$$

where σ_L (σ_R) is just the cross-section for jets produced to the left (right) of the normal to scattering plane. This does not require the full analysis of jet structure, like for handedness studies [24], and only the trust direction is necessary. At the same time, the cross-sections are much larger than in the photon case. In the proposed experiment $HERA - \vec{N}$, when 800 GeV proton beam would scatter on the polarized nucleon target, the expected statistical error for the jet left-right asymmetry is less than 10^{-3} . This would allow one to measure the asymmetry of order 10^{-2} , expected for "pessimistic" estimates based on the values (25),

From the theoretical point of view, these effects are just the asymmetries of quark and gluon production. They are insensitive to the fragmentation effects and provide as clear test of QCD, as a photon asymmetry.

Another interesting process, for which calculations are already performed, is the dilepton left-right asymmetry. The dilepton mass variation may be used to probe the quark-gluon correlation in various regions of the light-cone momentum fractions. At the same time, the background problem can be solved more easy in this case.

The quark gluon subprocesses contribute also to the single asymmetries of pion production. It is interesting, that the well-known problem of flavour dependence can be naturally solved, if the contribution of the fermionic poles is much larger than that of the gluonic poles.

The non-existence of the gluonic poles leads to the significant numerical difference between the single asymmetries of the gluon

$$A_{gg} = \frac{b_A(0, x) - b_V(0, x)}{f(x)} \frac{Mp_T}{m_T^2} \times \frac{(C_F - C_A/2)(1 - x_F)}{C_F(1 + x_F^2)} \frac{((x_F^4 + 1)C_A/2 - C_F x_F(1 - x_F)^2)}{(x_F(C_F - C_A/2) - (1 + x_F^2)C_F/2)},$$

and quark

$$\begin{aligned}
A_{gq} = & \frac{b_A(0, x) - b_V(0, x)}{f(x)} \frac{Mp_T}{m_T^2} \\
& \times \frac{1}{C_F(C_F(x_F^2(1 - x_F) + x_F^4/2) + C_A/2(2 - 4x_F + 3x_F^2 - x_F^3))} \\
& \times \left(C_F^2(x_F^2(x_F - 1)) - C_F C_A/2(x_F^3 - x_F^2 - x_F) + \right. \\
& \quad \left. + C_A^2/4(x_F^5 - 5x_F^4 + 11x_F^3 - 14x_F^2 + 9x_F - 4) \right)
\end{aligned}$$

production on the transverse polarized nucleon by the gluon from the unpolarized one. Namely, the latter is several times larger[25]. One may expect, that the pion single asymmetry is due to the pions resulting from the quark (not gluon!) fragmentation. As a result, the π^+ meson asymmetry is related to the correlation of gluon and u -quark, while π^- meson asymmetry is related to the correlation of the gluon and d -quark; π^0 can be produced by u - and d -quarks with equal probability.

Making use of sum rules relating the correlations to the "ordinary" quark distributions (8), valid for each flavour separately, one can easily get

$$A_{\pi^+} \sim \frac{\Delta u}{u}, \quad A_{\pi^-} \sim \frac{\Delta d}{d}, \quad A_{\pi^0} \sim \frac{\Delta u + \Delta d}{u + d}.$$

Note that mirror asymmetries for A_{π^+} and A_{π^-} and $A_{\pi^0} = 1/3 A_{\pi^+}$ can be obtained if $u = 2d$ and $\Delta u = -2\Delta d$, what is not far from experimental observation.

6 Conclusions

The earlier quantitative estimates of the twist-3 single asymmetries are dealing, in fact, only with the contributions of the gluonic poles. their smallness therefore should be interpreted as the argument against the original hypothesis of J. Qiu and G. Sterman about the domination of gluonic poles. The relative strength of fermionic and gluonic poles may be checked by the calculation of "dual" quark-gluon matrix element using QCD sum rules or lattice simulations.

As the solution of this problem by use of nonperturbative methods was not found yet, the models of twist 3 effects are especially important. We

are suggesting the simple model for the twist 3 part of g_2 structure function. It incorporates the Regge and phase space behavior, Burkhardt-Cottingham sum rule as well as another sum rule relating the first moments of g_1 and g_2 . It is found, that the smallness of the second moment is the result of the strong oscillations required by sum rules, while its absolute value may be fairly large at the region of $x \sim 0.1$. The values of twist-3 part of g_2 in this region are predicted in the proton (about 0.15) and neutron (about 0.8) cases, using the QCD sum rules calculations for the second moment. Such a behavior is supporting the domination of the fermionic poles over the gluonic ones, because it is the second moment, where the correlation producing the fermionic poles does not contribute.

The existing perturbative calculations allow one to study the various single asymmetries in the proton-nucleon scattering at 800 GeV (proposed experiment $HERA - \vec{N}$). The left-right asymmetries of jets and dileptons are especially interesting, as providing good statistics and offering the opportunity of clear tests of twist 3 QCD.

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